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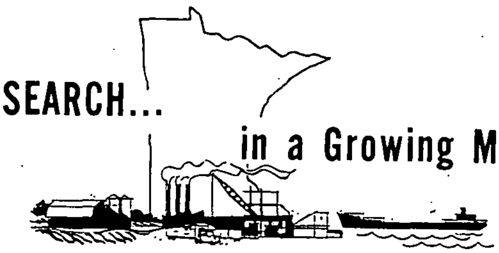
RESEARCH... in a Growing Minnesota



Several bulletins recently issued by the Minnesota Agricultural Experiment Station are now available from the Bulletin Room, University of Minnesota, St. Paul, Minnesota 55101. Please make requests by postcard, if possible, and list both number and title.

TB248. "Climate of Minnesota: Part III. Temperature and Its Application." Donald G. Baker and Joseph H. Strub, Jr. 64 pages.

SB474. "Consumer Use of Turkey." James F. Richards, Carroll V. Hess, and Milo H. Swanson. 16 pages.

SB476. "Factors Affecting Poultry Meat Yields." M. H. Swanson, C. W. Carlson, and J. L. Fry. 36 pages. (Also listed as North Central Regional Research Publication No. 158.)

MR60. "Soil Fertility Investigations With Corn on the Fayette Silt Loam and Associated Soils of Southeastern Minnesota." John Grava and Lowell D. Hanson. 28 pages.

MR61. "University of Minnesota Landscape Arboretum." 32 pages.

MR62. "The Minnesota Drain Tile Testing Machine." Philip W. Manson and Alden E. Domning. 20 pages.

MR63. "Marketing Minnesota's Dairy Products—Characteristics, Problems, and Needs." Jerome W. Hammond and Martin K. Christiansen. 68 pages.

Minnesota's Men of Science

This is the 43rd in a series introducing scientists at the University's Institute of Agriculture

Landis L. Boyd became head of the Department of Agricultural Engineering in August 1964.

He came to Minnesota from Cornell University, where he taught, conducted research, was active in extension education, and advised graduate students since 1948. Originally from Iowa, he received his college training at Iowa State University, Ames.

His research has dealt with several aspects of agricultural structures and farmstead mechanization, including poultry and dairy housing, crop storage facilities, timber evaluation, and timber joint design. He is author or coauthor of some two dozen publications.

In 1962-63, Boyd was an engineering design analyst for Allis-Chalmers Manufacturing Co., Milwaukee, where he trained engineers in use of digital computers for design and advised on development of an organizational structure for use of engineering programmers.

1. A poorly drained soil will exhibit an even greater lag than that shown in table 1. At depths greater than about 20 inches soil temperature in a well-drained soil does not vary from day to day.

Table 1. Approximate daily variations in the temperature of a well-drained soil

Depth	Maximum temperature occurrence	Minimum temperature occurrence	Range on a sunny summer day in a bare soil
Surface	Noon	Dawn	100° F.
0.5 in.	12:30-1 p.m.	½ hour after dawn	60° F.
2 in.	2 to 3 p.m.	½ to 1 hour after dawn	30° F.
4 in.	4 to 5 p.m.	1 to 2 hours after dawn	20° F.
8 in.	6 to 8 p.m.	3 to 4 hours after dawn	10° F.
12 in.	10 to 12 p.m.	6 to 8 hours after dawn	2° F.
16 in.	2 to 4 a.m.	9 to 11 hours after dawn	1° F.

The annual heating and cooling cycle of soil follows a wavelike pattern similar to that of the daily cycle. The depth to which the heat penetrates is about 42 feet at latitude 45° N. (St. Paul), and the lag in the occurrence of the maximum and minimum temperatures as a result is great, as shown in table 2.

Table 2. Approximate annual variations in the temperature of a well-drained soil

Depth	Maximum temperature occurrences	Minimum temperature occurrences	Range under a bare soil
4 in.	Early July	Early February	60° F.
32 in.	Early August	Early March	37° F.
64 in.	Early September	Early April	28° F.
10 ft.	Early October	Early May	16° F.
21 ft.	Mid-December	Mid-July	6° F.
42 ft.	Late April	Early November	1° F.

Canker Diseases of Trembling Aspen

Paul D. Manion and D. W. French

Aspen occupies about one-third, or 6 million acres, of the commercial forest land of Minnesota and is very common on much of the noncommercial forest land throughout the state. Trembling aspen (*Populus tremuloides*), known by other names such as aspen, quaking aspen, popple, and poplar, is the major tree species of this forest type. Bigtooth aspen, balsam poplar, and birch are other tree species found in lesser amounts in the aspen type.

Aspen is subject to many fungus and insect pests, and one of the most obvious groups of diseases is cankers. Two of the most important and common of these diseases are hypoxylon canker and nectria canker.

Hypoxlon Canker

Hypoxylon canker (figure 1) caused by the fungus *Hypoxylon pruinatum* is found on 24 percent of the trembling aspen in Minnesota. It is not restricted to weaker trees and is found as often on the best sites as on the poor sites. Young aspen are more susceptible and when infected with *H. pruinatum* are killed in 3 to 10 years by the girdling action of the fungus. Occasionally a tree is able to produce callus that temporarily slows the fungus, but usually the fungus grows so rapidly that little or no callus forms. The overall effect of hypoxlon canker on a stand is to reduce the stand density below desirable levels. This is not serious on marginal sites, but in commercial forests maximum wood production per acre is important.

Although it is not known how the fungus *H. pruinatum* enters a tree, it is speculated that the protective bark layers around branch axils are interrupted sufficiently to allow the fungus to enter the tree at this point. Once the fungus has successfully established itself in the tree it spreads through the outer sapwood, killing the cambium and producing a yellowish discoloration of the bark. The canker enlarges and eventually girdles the stem, resulting in the death of the tree.

Two or three years after infection the fungus produces masses of perithecia (figure 2) containing ascospores. These ascospores are forcibly shot out of the perithecia whenever free moisture is present. Following rains or during the winter when water from melting snow of ice runs down the tree, the perithecia shoot spores that are carried by wind currents to infect other trees. Although infection with these spores has not been accomplished experimentally with any degree of consistency, we assume that with the right environmental circumstances these spores are responsible for the spread of the disease.

There are no effective control measures for hypoxylon canker. Eradication of the cankered trees is definitely

Figure 1. Hypoxylon canker on trembling aspen. Canker on left illustrates the common association with branches; the canker on the right is older and stromata with spores are present.

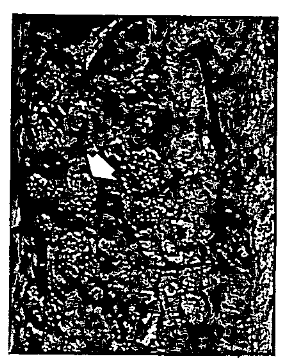


Figure 2. Stromata made up of masses of perithecia in which the spores of *Hypoxylon pruinatum* are produced.

Paul D. Manion is a research assistant, and David W. French is a professor in the Department of Plant Pathology and Physiology.

Figure 3. Nectria canker of trembling aspen showing the target-like appearance and the common association with a branch. This canker is more than 8 years old.

Figure 4. Perithecia of *Nectria galligena;* the infection is found throughout the range of trembling aspen in Minnesota. About 4 percent of the trees are infected.

not practical because an abundance of spores can be produced on a single canker that could be overlooked during the eradication program. Spores also are carried by wind from other infected stands. In one aspen stand of about 3 acres isolated by a surrounding stand of jack pine, all of the cankered trees have been removed every year since 1960. Although the aspen stand was isolated and every effort had been made to remove all the cankered trees, 23 newly infected trees were found in 1964. The amount of infection in a stand is related to stand density in such a way that the more dense the stand the fewer the infected trees. Thus, maintaining as high a stand density as feasible may help protect the trees.

Nectria Canker

The fungus *Nectria galligena* is the cause of nectria canker (figure 3) of trembling aspen and many other deciduous tree species. Other fungi such as *Ceratocystis fimbriata* and *Pholiota adiposa* may be involved in the canker development under certain conditions. About 4 percent of the trembling aspen in Minnesota are infected with *N. galligena.* Pockets of infected trees can be found throughout the range of aspen in the state. In contrast to hypoxylon canker, which does not seem to be correlated with site quality, nectria cankers on aspen are definitely correlated with site quality and are more common on trees growing on poor sites. In a given stand trees of larger diameter and dominant trees are more commonly infected than intermediate and suppressed trees.

The effect of the nectria fungus on trees is much less drastic than with hypoxylon canker, and many infected trees are harvested and used for pulpwood before they are killed by the fungus. Even growth rate is not measurably affected until a tree is 90 percent girdled.

N. galligena invades healthy trees through wounds or branch axils. The fungus grows very slowly in the outer sapwood, killing the cambium as it progresses. In response to the presence of the fungus the tree produces callus around the wound and temporarily halts progress of the fungus. But when the tree growth slows during the summer the fungus grows past the callus tissue and again spreads under the bark. This alternating growth of host and fungus produces callus ridges resulting in typical target-shaped cankers. Some time after infection the fungus produces ascospores in bright red lemon-shaped perithecia (figure 4). These ascospores are dispersed by the wind to infect other trees. However, even though trembling aspen is a common host for this fungus, perithecia seldom are found on this tree species. On the other hand, perithecia are produced on other susceptible hosts such as red maple, basswood, and paper birch. Ascospores formed on one host can infect any of the other hosts, therefore cankers on birch or maple can serve as a source of inoculum to infect trembling aspen.

As with hypoxylon canker, eradication is not an effective means of control. However, losses due to nectria canker in trembling aspen can be kept to a minimum through normal forest practice, which includes clear-cutting the trees before they become overmature.

About 6 miles north of the state capitol, Lake Vadnais, a storage reservoir in the St. Paul Water system, lies in the midst of a 300-acre experimental forest. The tract is named "The John H. Allison Forest," in honor of the author, who, since 1914, has supervised the establishment and management of . . .

The St. Paul Water Department's Manmade Forest

John H. Allison, *professor emeritus, School of Forestry*

This is a 300-acre experimental forest in which some 250 acres is in man-planted conifers. Most of the remaining 50 acres is in small parcels of naturally established 100-year-old oak.

The forest is owned by the St. Paul Water Department and has been brought to its present stage of development under an arrangement entered into between that Department and the University of Minnesota's School of Forestry in 1914. Its establishment and subequent development has been, and is being, carried for-